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RAYTHEON

Very Low Noise Operational Amplifier

OP-47

Features

- Very low noise
  Spectral noise density — 3nV/$\sqrt{Hz}$
  1/f noise corner frequency — 2.7Hz
- Very low V_{OS} drift
  0.2μV/Mo
  0.2μV/°C
- High gain — 1.8 x 10^6V/V
- High output drive capability — ±12V into 600Ω load
- High slew rate — 50V/μS (A_{VCL} > 400)
- Wide gain bandwidth product — 63MHz
- Good common mode rejection ratio — 126dB
- Low input offset voltage — 20μV
- Minimum low frequency noise — 0.08μV_{p-p}
  0.1Hz to 10Hz
- Low input bias and offset currents — 10nA

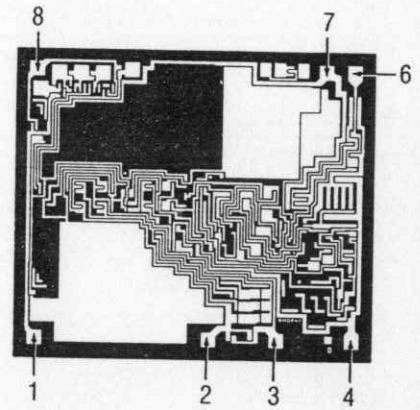
Description

The OP-47 is designed for instrumentation grade signal conditioning where low noise (both spectral density and burst), wide bandwidth, and high slew rate are required along with low input offset voltage, low input offset temperature coefficient, and low input bias currents in gains greater than or equal to 400. Digital nulling techniques performed at wafer sort make it feasible to guarantee temperature stable input offset voltages as low as 60μV. Input bias current cancellation techniques are used to obtain 10nA input bias currents.

The OP-47 is especially useful for instrumentation and professional quality audio applications in gains greater than or equal to 400. Applying the slew rate — power bandwidth equation ($f_p = SR/2\pi V_p$) the OP-47 will have an undistorted output at $8V_{p-p}$ of 900kHz. This device provides performance adequate for the most demanding high fidelity applications.

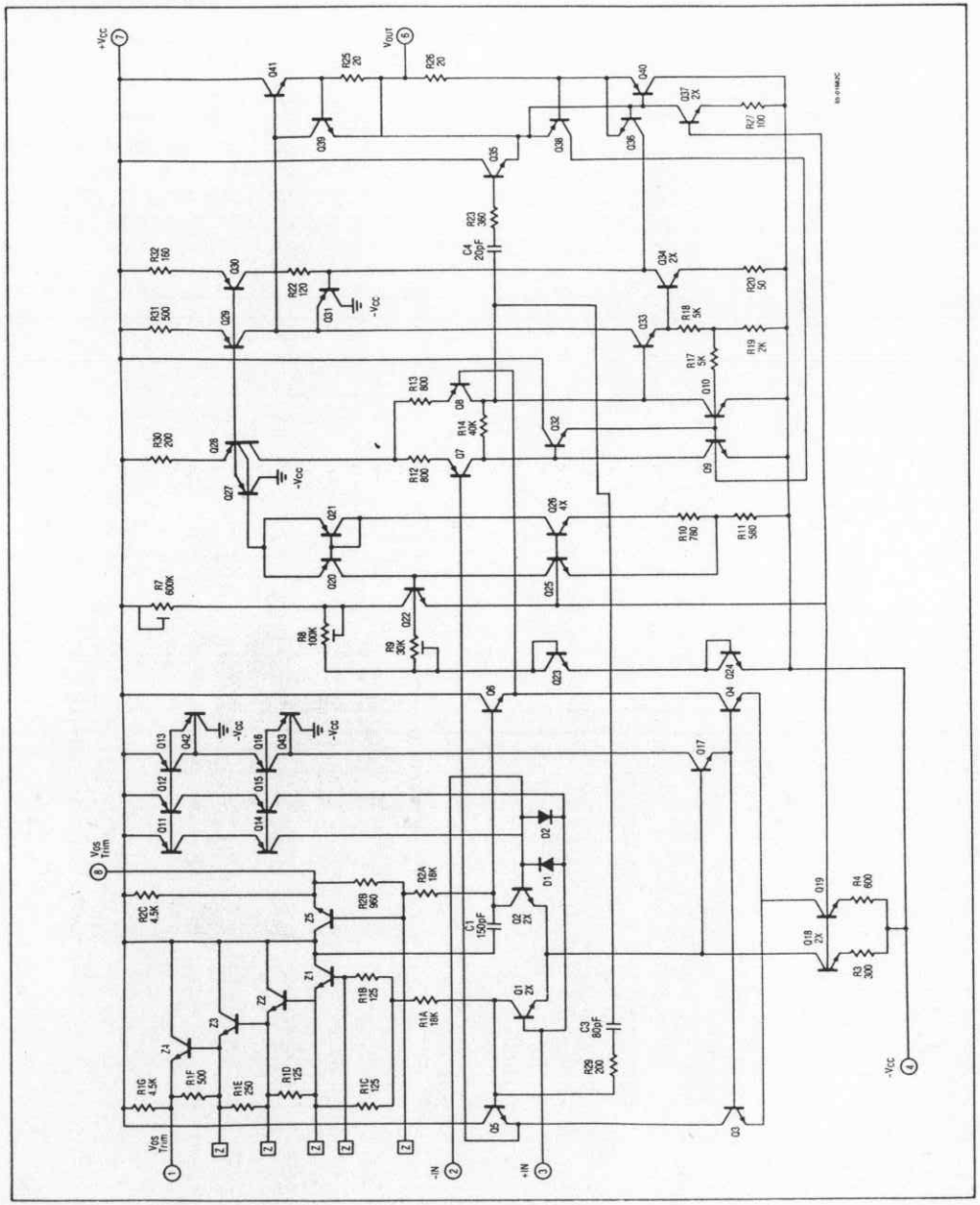
In addition to providing superior performance for the professional audio market the OP-47 design uniquely addresses the needs of the instrumentation designer. Power supply rejection and common mode rejection are both typically 120dB. Input offset voltage can be externally trimmed without affecting input offset voltage drift with temperature or time. The drift performance is, in fact, so good that the system designer must be cautioned that stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals are enough to degrade its performance. For this reason it is also important to keep both input terminals at the same relative temperature.

Mask Pattern

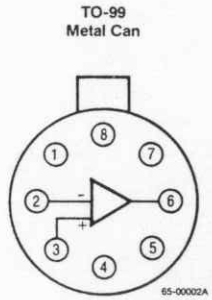


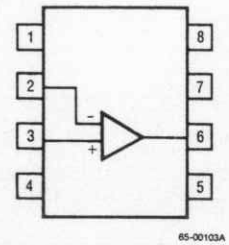
Die Size: 85 x 98 mils
Min. Pad Dimensions: 4 x 4 mils

Schematic Diagram



Connection Information





Pin	Function
1	V_{OS} Trim
2	Inverting Input
3	Non-Inverting Input
4	V–
6	Output
7	V+
8	V_{OS} Trim

Absolute Maximum Ratings

Supply Voltage ..... +22V
Input Voltage ..... ±22V
Differential Input Voltage ..... ±0.7V
Internal Power Dissipation 500mW
Output Short Circuit Duration ..... Indefinite
Storage Temperature
Range ..... –65°C to +150°C
Operating Temperature Range
OP-47B ..... –55°C to +125°C
OP-47F/G ..... 0°C to 70°C
Lead Temperature Range
(Soldering, 60 Sec.) ..... 300°C

Note: 1. For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

Thermal Characteristics

	TO-99 8-Lead Metal Can	8-Lead Plastic Dip
Max. Junction Temp.	175°C	125°C
Max. P_D T_A < 50°C	658mW	468mW
Therm. Res. θ_{JC}	50°C/W	
Therm. Res. θ_{JA}	190°C/W	160°C/W
For T_A > 50°C Derate at	5.26mW per °C	6.25mW per °C

Ordering Information

Part Number	Package	Operating Temperature Range
OP-47BT	TO-99	–55°C to +125°C
OP-47GT	TO-99	0°C to 70°C
OP-47GT	TO-99	0°C to 70°C
OP-47GNB	Plastic	0°C to 70°C

*MIL-STD-883 Level B Processing

Electrical Characteristics (V_S = ±15V and T_A = 25°C unless otherwise noted)

Parameters	Test Conditions	OP-47B/F			OP-47G			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[5]			20	60		30	100	μV
Long Term V_{OS} Stability[1,2]			0.3	1.5		0.4	2.0	μV/Mo
Input Offset Current			9.0	50		12	75	nA
Input Bias Current			±12	±55		±15	±80	nA
Input Noise Voltage[2]	0.1Hz to 10Hz		0.08	0.18		0.09	0.25	μV_{p-p}
Input Noise Voltage Density[2]	f_0 = 10Hz		3.5	5.5		3.8	8.0	nV
	f_0 = 30Hz		3.1	4.5		3.3	5.6	$\sqrt{Hz}$
	f_0 = 1000Hz		3.0	3.8		3.2	4.5	
Input Noise Current Density[2]	f_0 = 10Hz		1.7	4.0		1.7		pA
	f_0 = 30Hz		1.0	2.3		1.0		$\sqrt{Hz}$
	f_0 = 1000Hz		0.4	0.6		0.4	0.6	
Input Resistance (Diff. Mode)[4]		1.2	5.0		0.8	4.0		MΩ
Input Resistance (Com. Mode)			2.5			2.0		GΩ
Input Voltage Range[3]		±11	±12.3		±11	±12.3		V
Common Mode Rejection Ratio	V_{CM} = ±11V	106	123		100	120		dB
Power Supply Rejection Ratio	V_S = ±4V to ±18V	100	120		94	118		dB
Large Signal Voltage Gain	$R_L \geq 2k\Omega$, V_0 = ±10V	1000	1800		700	1500		V/mV
	$R_L \geq 1k\Omega$, V_0 = ±10V	800	1500			1500		
	V_0 = ±1V, V_S = ±4V[4]	250	700		200	500		
Maximum Output Voltage Swing[6]	$R_L \geq 2k\Omega$	±12	±13.8		±11.5	±13.5		V
	$R_L \geq 600\Omega$	±11	±12		±11	±12		
Slew Rate[4]	$R_L \geq 2k\Omega$	25	50		25	50		V/μS
Gain Bandwidth Prod.[4]	f_0 = 10kHz	45	70		45	70		MHz
	f_0 = 1MHz		45			45		
Open Loop Output Resistance	V_0 = 0, I_O = 0		70			70		Ω
Power Consumption			90	140		100	170	mW
Offset Adjustment Range	R_P = 10kΩ		±4.0			±4.0		mV

Notes:
1. Long term input offset voltage stability refers to the averaged trend line of V_{OS} vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5μV.
2. This parameter is tested on a sample basis only, and guaranteed to an LTPD of 10.
3. Caution the common mode input range is a function of supply voltage, see typical performance curves. Also, the input protection diodes do not allow the device to be removed or inserted into the circuit without first removing power.
4. Parameter is guaranteed by design and is not tested.
5. Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.
6. CAUTION: positive output voltage swing should never exceed the minimum specified limits or large oscillation voltages will occur.

Electrical Characteristics (V_S = ±15V, -55°C ≤ T_A ≤+125°C unless otherwise noted)

Parameters	Test Conditions	OP-47B			Units
		Min	Typ	Max	
Input Offset Voltage[1]			50	200	μ
Average Input Offset Drift[2]			0.3	1.3	μV/°C
Input Offset Current			22	85	nA
Input Bias Current			±28	±95	nA
Input Voltage Range		±10.3	±11.5		V
Common Mode Rejection Ratio	V_{CM} = ±10V	100	119		dB
Power Supply Rejection Ratio	V_S = ±4.5V to ±18V	94	114		dB
Large Signal Voltage Gain	$R_L \geq 2k\Omega$, V_0 = ±10V	500	1000		V/mV
Maximum Output Voltage Swing	$R_L \geq 2k\Omega$	±11	±13.2		V

Notes:
1. Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.
2. $T_C V_{OS}$ performance is guaranteed unnulled or when nulled with R_P = 8kΩ to 20kΩ.

Typical Electrical Characteristics (V_S = ±15V, 0°C ≤ T_A ≤ 70°C unless otherwise noted)

Parameters	Test Conditions	OP-47F			OP-47G			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[5]			40	140		55	220	μV
Average Input Offset Drift			0.3	1.3		0.4	1.8	μV/°C
Input Offset Current			14	85		20	135	nA
Input Bias Current			±18	±95		±25	±150	nA
Input Voltage Range		±10.5	±11.8		±10.5	±11.8		V
Common Mode Rejection Ratio	V_{CM} = ±10V	102	121		96	118		dB
Power Supply Rejection Ratio	V_S = ±4.5V to ±18V	96	116		90	114		dB
Large Signal Voltage Gain	$R_L \geq 2k\Omega$, V_0 = ±10V	700	1300		450	1000		V/mV
Maximum Output Voltage Swing	$R_L \geq 2k\Omega$	±11.4	±13.5		±11.0	±13.3		V

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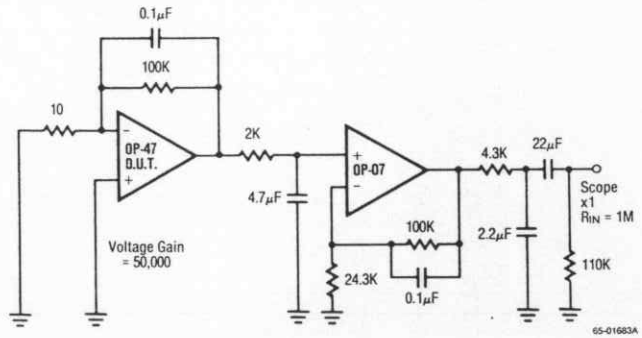
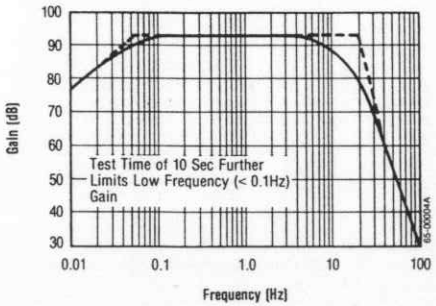
Typical Performance Characteristics



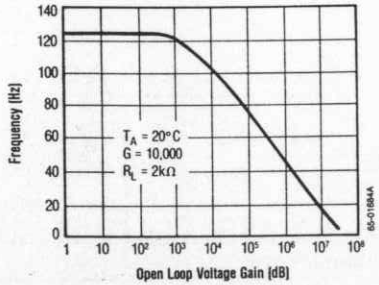
Note: All Capacitor values are for non polarized capacitors only

0.1Hz to 10Hz Noise Test Circuit

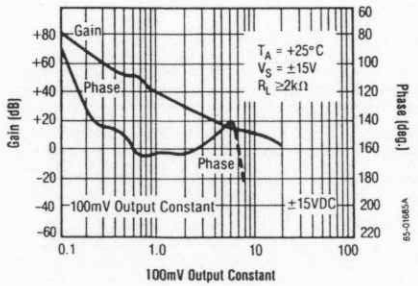
0.1Hz to 10Hz p-p Noise Tester Frequency Response



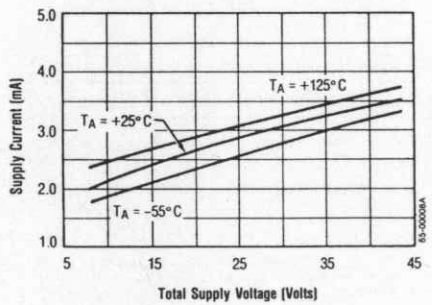
Open Loop Gain vs Frequency



Gain & Phase Shift vs Frequency



Supply Current vs Supply Voltage



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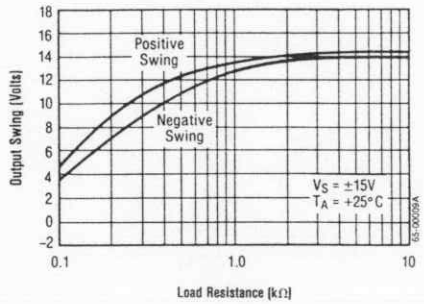
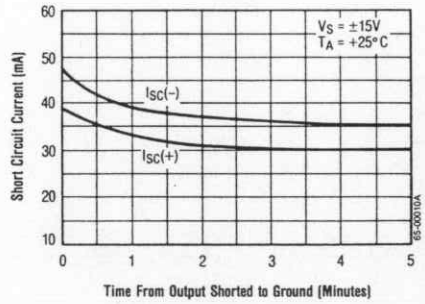
Typical Performance Characteristics (Continued)

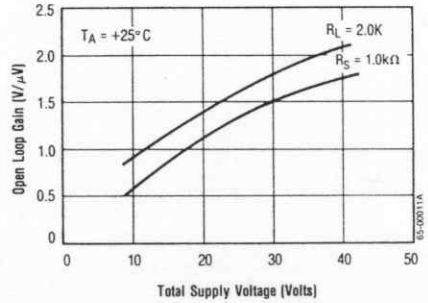
Maximum Output Swing vs Resistive Load



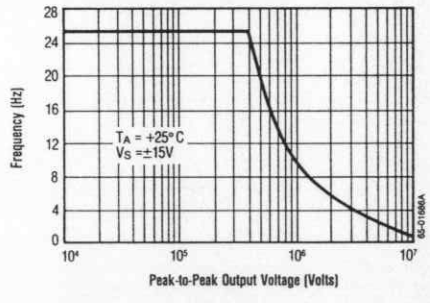
Short Circuit Current vs Time



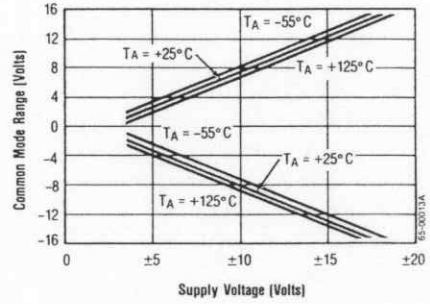
Open Loop Voltage Gain vs Supply Voltage



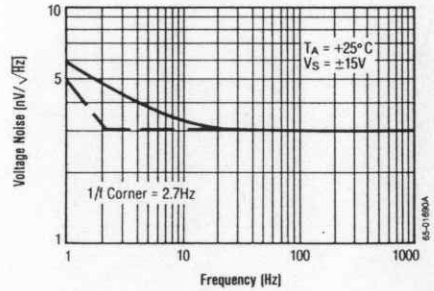
Maximum Undistorted Output vs Frequency



Common Mode Input Range vs Supply Voltage



OP-47 Voltage Noise vs Frequency



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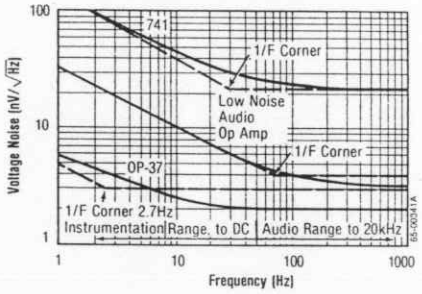
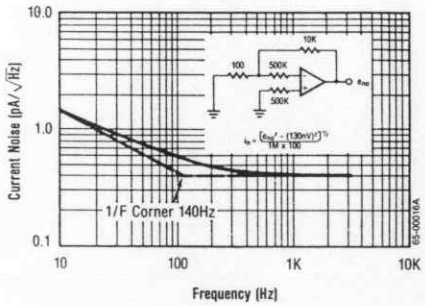
Typical Performance Characteristics (Continued)

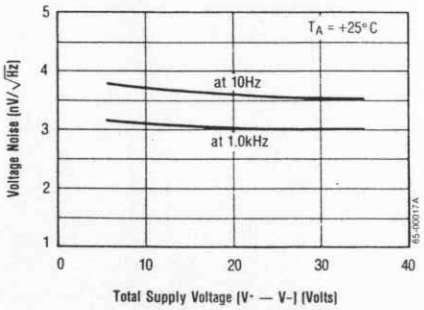
A Comparison of Op Amp Voltage Noise Spectrums



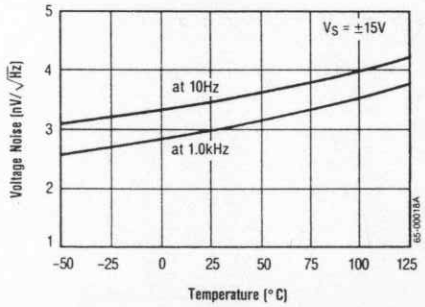
Current Noise vs Frequency



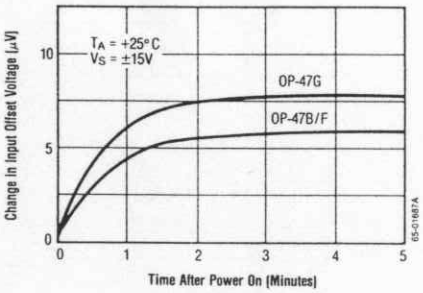
Voltage Noise vs Supply Voltage



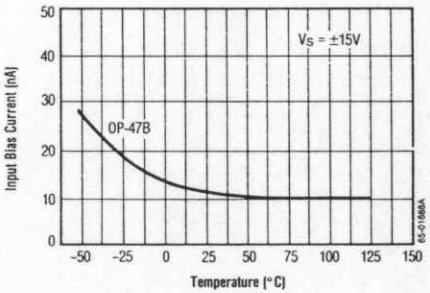
Voltage Noise vs Temperature



Warm-Up Drift



Input Bias Current vs Temperature



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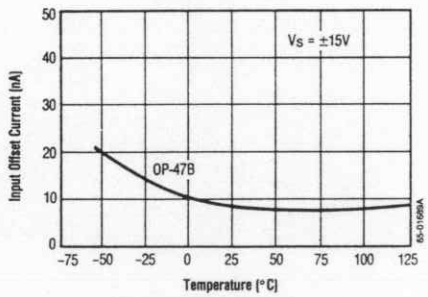
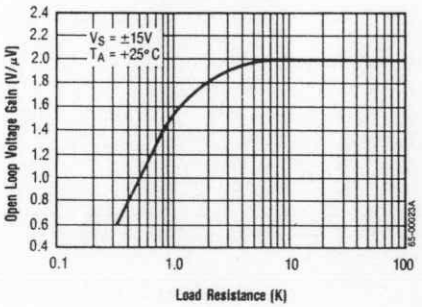
Typical Performance Characteristics (Continued)

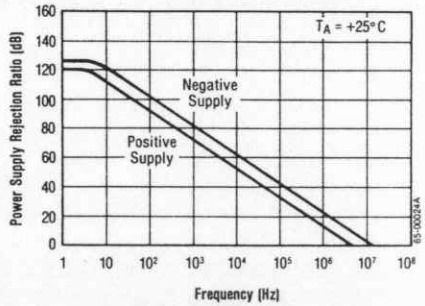
Input Offset Current vs Temperature



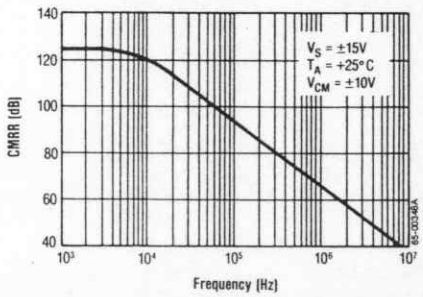
Open Loop Voltage Gain vs Load Resistance



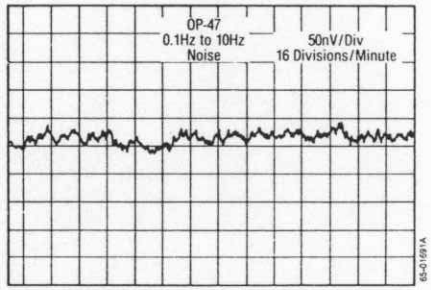
PSRR vs Frequency



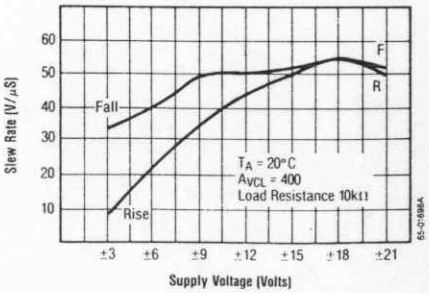
CMRR vs Frequency



OP-47 0.1 Hz to 10Hz Peak-to-Peak Noise
Vertical Scale 50 nV/Division
Recorder Speed 8 Divisions/Min



Supply Voltage vs Slew Rate



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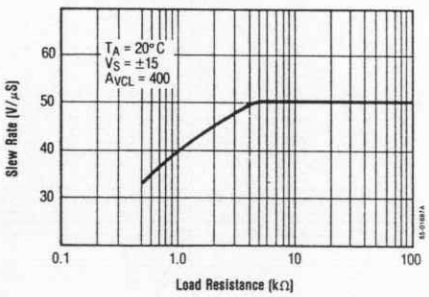
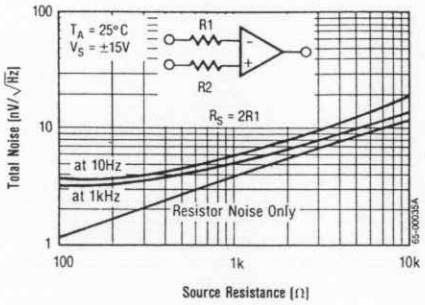
Typical Performance Characteristics (Continued)

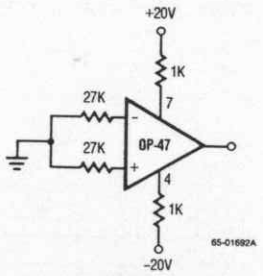
Load Resistance vs Slew Rate



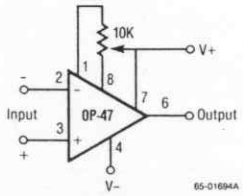
Total Noise vs Source Resistance



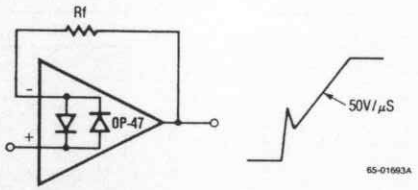
Voltage noise vs source resistance for the difference amplifier. Noise performance shown is for V_S = ±15V, T_A = +25°C, and $R_S = R_1 + R_2$



Burn-In Circuit



Offset Nulling Circuit



When Rf ≤ 100Ω and the input is driven with a fast, large signal pulse (≥ 1V), the output waveform will look as shown.

Large Signal Transient Response

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Typical Applications

Low Impedance Microphone Preamp (Figure 1)
In this preamp the transformer converts the low microphone impedance up to a value that is close to the optimum source impedance required by the OP-47 for best noise performance. The optimum source impedance can be calculated as the ratio of e_n/i_n which for the OP-47 is approximately 7000Ω. Fortunately the noise performance does not degrade appreciably until the source impedance is four or five times this optimum value. The source impedance at the output of this transformer of 15kΩ still provides near optimum noise performance. (A high quality audio transformer with a step up ratio of 6.7 to one is not available.) C1 rolls off the high frequency response at 90kHz giving a noise power bandwidth of 140kHz.

Instrumentation
The OP-47 is particularly adaptable to instrumentation applications. When wired into a single op amp difference amplifier configuration, the OP-47 exhibits outstanding common mode rejection ratio. The spot voltage noise is so low that it is dominated almost entirely by the resistor Johnson noise.

The three op amp instrumentation amplifier of Figure 2 avoids the low input impedance characteristics of difference amplifiers. The noise increases because two amplifiers are contributing to the input voltage spectral noise. The noise contribution, exclusive of resistor Johnson noise, increases by slightly more than the $\sqrt{2}$. The spectral noise voltage increases from approximately $3nV/\sqrt{Hz}$ to approximately $4.9nV/\sqrt{Hz}$, with the third amplifier contributing about 10% of the noise. The gain of the input amplifier is set at 25 and the second stage at 400 for an overall gain of 10000. R7 is trimmed to optimize the common mode rejection (CMRR) with frequency. With balanced source resistors a CMRR of 100dB is achieved. With a 1kΩ source impedance imbalance CMRR is degraded to 80dB at 5kHz due to the finite (3GΩ) input impedance.

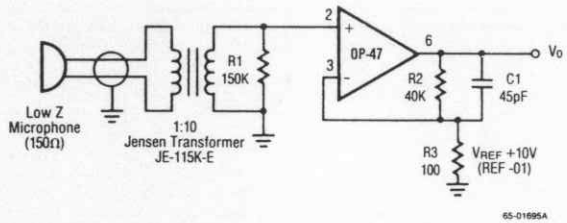


Figure 1. Low Impedance Microphone Preamplifier

RAYTHEON

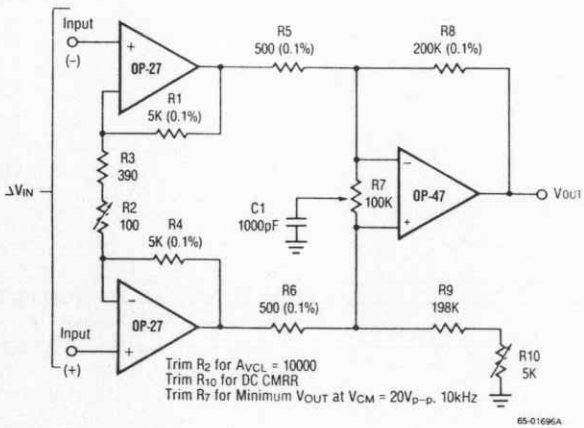
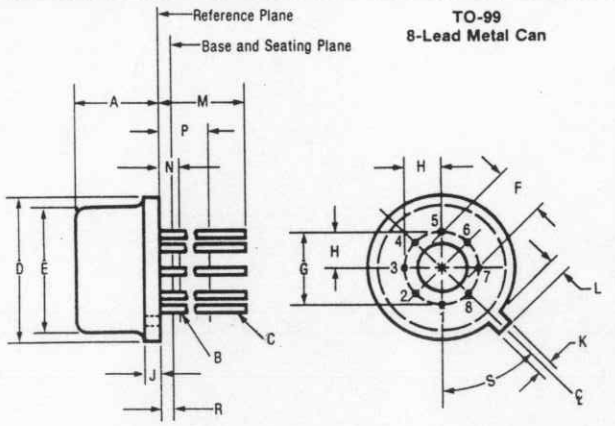


Figure 2. Three Op Amp IC Instrumentation Amplifier

Packaging Information

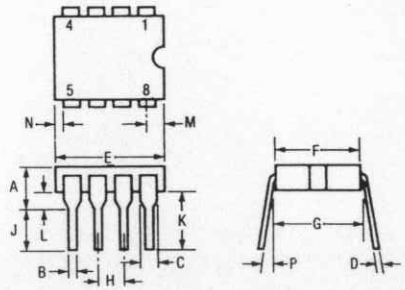
TO-99
8-Lead Metal Can



Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	.165	.185	4.19	4.70
B	.016	.019	.41	.48
C	.016	.021	.41	.53
D	.335	.370	8.51	9.40
E	.305	.335	7.75	8.51
F	.120	.160	3.05	4.06
G	.200 BSC		5.08 BSC	
H	.100 BSC		2.54 BSC	
J		.040		1.02
K	.027	.034	.69	.86
L	.027	.045	.69	1.14
M	.500	.750	12.70	19.05
N		.050		1.27
P	.250		6.35	
R	.010	.045	.25	1.14
S	45° BSC		45° BSC	

65-01189B

8-Lead
Plastic Dual-In Line



Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	.115	.125	2.92	3.17
B	.015	.021	0.38	0.53
C	.030	.070	0.76	1.78
D	.010	.015	0.25	0.38
E	.360	.400	9.14	10.16
F	.240	.260	6.09	6.60
G	.290	.310	7.37	7.87
H	.090	.110	2.29	2.79
J	.120	.135	3.05	3.43
K	.140	.165	3.56	4.18
L	.020	.030	0.51	0.75
M	.025	.050	0.64	1.27
N	.005		0.13	
P	0°	15°	0°	15°

65-01192B